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30 May 1980

# USSR Report

## ENERGY

No. 15

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## ELECTRIC POWER

### PRESENT, FUTURE ENERGY USE IN LITHUANIA

Vilnius VALSTIECIU LAIKRASTIS in Lithuanian 22 Dec 79 p 4

[The conversation of the VALSTIECIU LAIKRASTIS correspondent with Alrigrad Strumba, deputy chief of the Central Administration of Energy Production and Electrification of the Lithuanian SSR]

[Text] [Question] The electric power stations of Soviet Lithuania produced this year more than 11 billion kilowatthours of electric energy. Tell us, please, is it enough for our republic?

[Answer] In the development of the republic's industry and agriculture, the electric energy is being developed on a priority basis. It is understandable; energy is the basis of our economy.

Until now we produced more electric energy than we consumed, and we used to give the surplus to the republics belonging to the Northwestern Electric Energy System of the USSR. And now we have reached the balance point: We ourselves use all the energy produced. By next year we will have to borrow electricity from the neighbors.

Naturally, not for long. Plans are made to build in Vilnius a large thermal electric power station; new capabilities will also be added to the electric power station of the Mazeikiai oil refinery works. However, only after the nuclear power station in Ignalina begins functioning will the republic be able to provide electric energy for the long range plans.

By the way, I would like to point out that during the course of one year 150 times more electricity is produced in Lithuania now than it was during the final years of the bourgeois administration.

[Question] Not long ago I had the opportunity to visit the construction site of the nuclear power station in Ignalina. Most noticeable is its gigantic scale....

[Answer] The nuclear power station in Ignalina, which is being constructed in conformity to the decrees of the 24th CPSU Congress, is indeed unique.

There is no equal in the world. In each of its reactors could "fit" almost the whole VRE [expansion unknown] of Lithuania! The nuclear giant will produce 21 billion kilowatthours of electricity per year--almost twice as much as is produced by all the energy power stations today.

[Question] Why is a nuclear and not a themal power station being built?

[Answer] The republic brings in all the fuel from distant economic regions of the country. Keeping in mind that a great deal of it is needed (the electric power works of Elektrenai alone use about 50,000 tank-cars of black oil annually), it is easy to imagine the cost of fuel delivery. Nuclear fuel, of course, is incomparably more expensive but very little of it is needed. Therefore, while to build a nuclear power station costs more than a regular electric power station, these expenses will be soon recovered: The cost of one "nuclear kilowatthour" will be almost 1 and 1/2 times less.

Besides, a pumpstorage electric power station which will become a peculiar electric energy "bank," is already under construction in Kaisedoriai rayon. During the night, when the plants are idle and there is electric energy surplus, the pumpstorage electric power station uses it to raise the water from Kaunas sea to very great heights; during the day the freed water, as in a hydropower electric station, will reproduce the energy spent.

[Question] And how is the availability of electricity being increased in rural areas?

[Answer] For personal, housekeeping purposes, the rural resident consumes now almost as much electric energy as the city resident. Therefore, according to the calculations of sociologists, a family using electric appliances saves 700 hours of personal time each year, which can be used for self-education, rest, etc. A washing machine and a refrigerator alone save 200 hours!

In terms of electric power use for production, the agricultural worker is still quite behind the industrial worker. The difference, however, is gradually decreasing. It is hoped that next year every worker in agriculture will be "assisted" by 54,000 kilowatthours. Let us compare: In 1965 this index barely reached 400 kilowatthours.

The use of electric power in agriculture in general increases 1 and 1/2 times faster than in industry. Electric power is now being used in almost all agricultural tasks. Three hundred fifty thousand electric motors in use in rural areas help to clean and dry the grain, milk the cows, water the fields, clean the stables, and so on. Presently, energy specialists, together with agricultural workers, are searching for methods to expand the application of electric energy in thermal processes; in the preservation of feed, for instance, in the heating of cattle farms. This is very important because the creation of an optimal microclimate enables one to decrease not only the cost of labor but also the use of feed.

[Question] And what is being done to increase electric energy's reliability?

[Answer] In carrying out the decree of the CPSU CC and the Council of Ministers of the USSR, "The means for further development of agricultural electrification," during this five-year plan, the employees of the republic's energy services have already laid several thousand new electric supply lines. Electricity supply was greatly improved through the 330 kilowatt lines between Kaunas and Grodno and between Klaipeda and Lepoja, which were put in service several years ago. Quite a few substations in the rayons are now being fed not by a single but by a circuit line. This helps to avoid prolonged electric supply failures. Much is being done to improve the low tension electric supply lines in rural areas. Since the beginning of the five-year plan, for instance, 8,000 kms of defective lines and more than 10,000 power poles have been replaced. We strive to do away in the near future with all the emergency low tension lines in the rural areas.

Electric power is a great national treasure. It must, therefore, be used rationally, thriftily and economically. Economic executives, specialists and energy specialists must do everything to assure that each kilowatthour brings the most benefits.

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FUELS

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# GPA-TS-6, THREE GAS TRANSFER UNITS IMPROVED

Moscow GAZOVAYA PROMYSHLENNOST' in Russian No 12, Dec 79 pp 8-11

[Article by S. G. Sokolov, Yu. F. Komlyk, V. P. Parafeynik]

[Text] Such characteristics of the GPA-Ts-6,3 gas transfer units as the possibility of building stations without significant capital expenditures, high level of plant prefabrication, portability, the presence of a full-head booster and high-rpm aircraft drive insures significant advantages over the Soviet units of other types for construction of line and booster compression stations under various climatic conditions and the construction of underground gas storages.

The GPA-Ts-6,3 gas transfer units is a device, all the assemblies of which are in containers. Provision is made for modular delivery to the customer with a high degree of plant prefabrication which, as a result, significantly reduces the installation and start-up time of the compressor stations.

The comparatively low specific metal consumption, the specific intake of power and the specific area occupied by the installation distinguish this unit advantageously from the units which have a general-industrial type gas turbine drive (see Table 1).

The advantages of the modular-container gas transfer units (GPA) have a special effect on the lowering of the specific capital expenditures and acceleration of the introduction of the compressor stations into operation. The reduction of the time required to introduce the compressor stations into operation with the GPA-Ts-6,3 type units by comparison with the compressor station equipped with units with general-industrial type gas turbine drive significantly decreases the times for assimilation of capacity in the gas industry and insures the design conditions of operating the gas lines. As for the latter, the most effective in this respect will be the application of the new versions of the GPA-Ts-6,3 type units developed at the present time for the booster compressor stations, especially in depleted fields.

The series production of the GPA-Ts-6,3/56 transfer pump has been realized since 1973. During the process of completion and experimental operation of the unit a number of structural and technological deficiencies were discovered: wear of the end seals of the pump as a result of an insufficient degree of purification of the process gas and oil in the sealing system, limited reserves of the network water purifiers, leaking of the pump housing through the horizontal split, failure of the bearing assembly of the power turbine, low operating reserve of the drive gears of the main pump of the lubrication system, leakage of oil out of the air oil-coolers and the torsion bar housing, and so on.

The elimination of the indicated deficiencies was provided for by introducing a number of new technical designs.

It must be noted that the GPA-Ts-6,3 type units do not have Soviet analogs, and they have been assimilated in our country for the first time. Accordingly, the Ministry of the Gas Industry and adjacent ministries have organized efforts at further improvement of these units, which is constantly being accomplished.

Table 1

| Indexes | GPA-Ts-6,3/56 | GT-6-750 of the Urals turbomotor plant | M3142 General Electric |
|---|---|---|---|
| Specific power intake, kilowatts/$m^3$/min | 32.14 | 32.37 | 32.08 |
| Specific metal consumption kg/$m^3$/min | 268 | 375.64 | 354.73 |
| Specific area, $m^2/m^3$/min | 0.149 | 0.222 | 0.158 |
| Fuel gas consumption (rated), $m^3$/hr | 2360 | 2600 | -- |

Note. The calculation of the specific indexes was made under comparable conditions without VOU, exhaust pipe and container of the unit using the data of the VNIIgaza Institute. The fuel gas consumption is determined by the results of testing the Ts-6,3/56M gas transfer unit with a lower heat of combustion of the fuel gas of 8578 kcal/$m^3$.

Considering the accumulated experience, a set of measures has been developed, approved by the ministry leadership and introduced, which provide for improving the structural design of the unit, provision of spare parts and materials, and improvement of the maintenance and repair services at the compressor stations.

The introduction of the planned measures at the compressor stations is being realized by information letters and bulletins prepared by the developer organization and coordinated with the manufacturing plant and the Orgenergogaz. Along with the information letter, the developer organization sends a set of design and process documents to the Orgenergogaz, which distributes it through the corresponding production associations of the Ministry of the Gas Industry to each compressor station for use.

The introduction of noted measures on the newly produced unit is carried out in parallel. The developer organizations correct the technical documentation by which the manufacturing plants realize series production.

Significant work with respect to improving the GPA-Ts-6,3 units is being done by the efficiency experts among the industrial, engineering and technical workers both directly at the compressor stations and at the manufacturing plants.

In 1975-1978 measures were introduced at the compressor stations which have a significant effect on raising the level of reliability and operation and maintenance of the units.

The most significant of them can be considered to be the following: the finishing of the automation system, introduction of the IV-500ST vibration measuring equipment, installation of the modified torsion bar housings, replacement of the copper pulse tubes by steel ones, improvement of the structural design of the snail-case exhaust housing and diffuser, improvement of the seal and operating reliability of the gas and oil systems, the introduction of a new design for the air line to blow the stator of the free turbine, improvement of the structural design of the sealed adapter between the engine compartment and the intake chamber, introduction of the modifed design for the rear bearing of the power turbine, and so on.

The improvement of the GPA-Ts-6,3/56 units during operation and maintenance and series production has increased their reliability significantly. This is confirmed by the operating data on the units for 1977-1978 in three associations of the Ministry of the Gas Industry (see Table 2).

From Table 2 it is obvious that in 1978 the time worked per failure more than doubled.

In 1978 individual compressor stations of the Ministry of the Gas Industry achieved results which exceeded the corresponding mean indexes of the gas transfer units with gas turbine drive of the general-industrial type. Thus, in 1978 the following average time worked per failure was achieved at a number of compressor stations: 8720 hours at the Shemordan compressor station; 6030 hours at the Perm' compressor station and 4994 hours at the Votkinsk compressor station. The presented data indicate significant reserves to increase the operating efficiency of the units as a result of improving their operating level.

Since the second half of 1977 the Sumy Machine Building Production Association imeni M. V. Frunze has introduced the GPA-Ts-6,3/56M into series production. By comparison with the previous version it has a number of advantages insuring higher reliability indexes.

A significant amount of effort is being aimed at improving the GPA-Ts-6,3/56. It is being performed at the present time by direct contracts with the Gor'kiytransgaz Association. The basic projects are as follows: improvement of the end seals of the pumps in order to reduce the oil losses; improvement of the control and measuring instruments and automation equipment systems; reduction of the erosion wear of the impellers; introduction of the snail-case housing with ejection cooling, remote type temperature regulators (RTP-32, RTP-60) providing for automatic oil temperature regulation at the entrance to the engine and the pump; the development and introduction of a process for purging the gas-air channel of the gas transfer unit.

The operating conditions of the gas transfer unit at the compressor stations are being investigated to develop recommendations for most efficient operation and maintenance and the creation of the required versions of the direct-flow section of the pumps, including a 1.5 pressure booster stage.

Table 2

| Indexes | Gor'kiy transgaz | Orenburg transgaz | Lentransgaz |
|---|---|---|---|
| Total units in operation | $\frac{56}{62}$ | $\frac{15}{15}$ | $\frac{7}{13}$ |
| Time the units spend, hours: | | | |
| in operation | $\frac{313985}{332332}$ | $\frac{64306}{64585}$ | $\frac{32406}{46790}$ |
| in forced idle time | $\frac{14529}{11639}$ | $\frac{3139}{2697}$ | $\frac{4032}{5798}$ |
| Time worked per failure, hrs | $\frac{862}{1867}$ | $\frac{684}{1346}$ | $\frac{360}{1800}$ |
| Availability | $\frac{0.956}{0.966}$ | $\frac{0.953}{0.960}$ | $\frac{0.889}{0.880}$ |

Note. The data for 1977 are presented in the numerator, and for 1978, in the denominator. The indexes are determined by the data from the production associations of the Ministry of the Gas Industry.

The effective solution of many problems connected with improving the series manufactured and maintained gas transfer units is promoted by the creation of an experimental finishing full-scale test unit on which a great deal of work is being done to improve the technical level of the assemblies and systems, to create and assimilate new versions of the GPA-Ts-6,3 type units.

In particular, in accordance with the recommendations of the Interdepartmental Commission in 1979 a large volume of design work was done with respect to further improvement of the GPA-Ts-6,3/56M unit under series production conditions.

The structural design of the panel-type container has been developed and introduced which provides for the application of two-ton hoists in the pump compartment, regulation of the cooling air flow rate through the engine compartment, and a higher level of repairability of the unit. The new design of the container corresponds to the requirements of technical aesthetics.

A new design of the oil cooler module providing for emergency drainage of the oil and automatic cleaning of the air and protection against dust are used in the oil system. The filters in the lubrication system and seals will be replaced without shutting down the unit. A number of measures are being introduced with respect to lowering the noise level during operation of the unit, in particular, as a result of muffling the noise of the VOU fan and the entrance of the air scoop for cooling the stator of the free turbine of the aircraft drive.

The system of control and measuring instruments and automation equipment has been significantly improved with respect to the schematic design, structural elements and control structure. The new structural design of the panels corresponds to the requirements of ergonomics and technical aesthetics.

The positive experience of operating the units under various climatic conditions, the assimilation of series production of the modified GPA-Ts-6,3/56M will in the near future make it possible to solve a problem of great national economic importance -- the creation of a parametric series of the GPA-Ts-6,3 type units for various purposes with standardization level.

The analysis of the announced demand of the gas industry and the preliminary design development indicate that on the basis of the GPA-Ts-6,3/56M it is possible to create a parametric series of standardized booster units with pumping pressure of 17, 28, 41 and 66 kg/cm$^2$, a power of 6.3 mWt and a pressure boost of 1.45 to 1.7.

The developer organizations and the manufacturing plants have attacked the practical realization of this goal. A test model of the GPA-Ts-6,3/66 has been manufactured and installed for testing. The purpose of the tests is to evaluate the technical possibilities of the creation (on the basis of the series unit) of the reliably operating unit for transferring natural gas containing a significant amount of hydrogen sulfide. During the tests it is necessary to check the fitness of a number of the pump assemblies, the oil system, the control and measuring instruments and automation equipment in an environment of hydrogen sulfide. The GPA-Ts-6,3/40 is being designed, and an experimental model is to be built in 1980.

Work has started on the creation of a cooling unit with aircraft type drive with a cooling capacity to 16 million kcal/hr based on the GPA-Ts-6,3/56M. The unit is designed to support the operation of gas mains in permafrost regions.

The creation of the GPA-Ts-6,3/56 type units with full-head booster in a housing with horizontal split is a great achievement of Soviet compressor building. The presence of a horizontal split in the pump housing with modular-container composition of the unit was a significant advantage during the finish work on it. According[3], it appears expedient simultaneously with the creation of the "barrel" type pump to manufacture and test an experimental model of a 76 kg/cm$^2$ pump in a series housing. The assimilation of this pump in production and operation would make it possible to standardize the new rebuilt GPA-Ts-6,3/76 unit with the series unit and at the same time to obtain a significant cost benefit both in series production and in operation and maintenance. At the same time the assimilation of the "barrel" type compressors will be basic to the creation of the multistage designs of the pump for units of various purposes.

The further development of the gas industry, and in particular, the creation of a network of large underground natural storages will state the goal of assimilating the production of Soviet units with 100-120 kg/cm$^2$ gas turbine drive and a 1.45-1.8 pressure boosting stage. As the calculated analysis shows, the creation of such units is expedient on the basis of the series and newly assimilated GPA-Ts-6,3.

The experience in the design of the modular-container units considering various climatic conditions indicates that the creation of an all-purpose unit satisfying all the operating requirements under the conditions of Central Asia and the Far North is inexpedient in connection with the contradictoriness of the imposed requirements, unjustifiable complication of the design and a significant increase in its metal consumption. It is expedient to assimilate two versions of the modular-container type unit: for the regions in the central belt and the Far North; the regions of the South and Central Asia. The problem of the creation of an all-purpose unit can be solved differently in the presence of a shelter or light weight building. In this case the unit designed for operation under various climatic conditions will differ only by the construction of the VOU.

Thus, the experience in creating the GPA-Ts-6,3 type units and the analysis of the prospective requirement of the gas industry for compressor equipment permit the following conclusions to be drawn.

The work of improving the units of this type must be continued in order to accumulate the positive experience of their operation and maintenance in the various climatic zones of the country.

On the basis of the series type GPA-Ts-6,3/56M machine, the creation of a parametric series of booster units is possible with a pressure of 17, 28, 41 and 66 kg/cm$^2$ and a 1.45-1.7 pressure step-up stage for operation under various climatic conditions.

The assimilation of the design of the "barrel" type pumps will permit units to be built for 76, 100 and 120 kg/cm$^2$ pressures for line and booster compressor stations and also the underground gas storage stations with a pressure booster stage of 1.45 to 1.8.

When creating the modular-container gas transfer units designed for operation in the regions of the Far North, South and Central Asia, it is necessary to be guided by the requirements on their operating reliability in the compressor station system while insuring optimal technical-economic indexes of the individual units.

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FUELS

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## IMPROVING RELIABILITY OF ELECTRICALLY DRIVEN GAS TRANSFER UNITS

Moscow GAZOVAYA PROMYSHLENNOST' in Russian No 12, Dec 79 pp 11-14

[Article by Ye. B. Golubev, A. F. Shkuta, Ukhta Industrial Institute, Ministry of the Gas Industry]

[Text] The problem of determining losses from interruptions of the electric power supply for compressor stations is a highly urgent problem. Its solution will make a scientifically substantiated approach possible for the determination of the classification of the electrical receivers of the compressor station and the optimal degree of their reliability.

The problem of reliability and effectiveness of the functioning of the gas mains is complex and multilevel. The reliability of the operation of the gas line depends approximately to equal degree on the reliability of the line part and the compressor stations.

It is possible and necessary to control the reliability. The reliability of the individual objects, in particular, the compressor stations must begin to be thought of simultaneously with the development of the assignment for design and in all subsequent stages. The greatest effect is achieved when an expedient level of reliability is economically substantiated.

The analysis and calculation of the reliability in the design steps are a priori analysis which, however, is somewhat facilitated when using the information already available about the functioning of the existing objects prepared correspondingly for the making of recommendations.

At the Moscow Institute of Petrochemical and Gas Industry imeni I. M. Gubkin and the Ukhta Industrial Institute jointly with the Main Power Engineering Administration of the Ministry of the Gas Industry, work is being done to generalize the experience of the operation and maintenance of the electrically driven compressor stations (EP KS). Some of the results and the recommendations with respect to improving the reliability are presented in this article.

The structural reliability diagram of the EP KS can be represented in the form of a chain of series-connected elements (Figure 1): the electric power system (EES); the electric power transmission lines, including all line equipment (LEP); the high-voltage distribution emf (RU VN), including the step-down power transformer; the low-voltage distributing unit (RU NN); the gas transfer units (GPA). Depending on the stated problems, each of these elements can be broken down into smaller elements or consolidated.

Before talking about improving the reliability of the operation of the compressor stations on the whole as an inseparable component part of the gas transport system, on which the operation of the gas mains depends to a great extent, it is necessary to determine the greatest "bottlenecks" in the system. For this purpose the reporting data has been analysed from the Orgenergogaz for 1971-1977. It was discovered that the greater part of the forced shutdowns of both the electrically driven and gas turbine units are caused by interruptions in the electric power supply (see Figure 2).

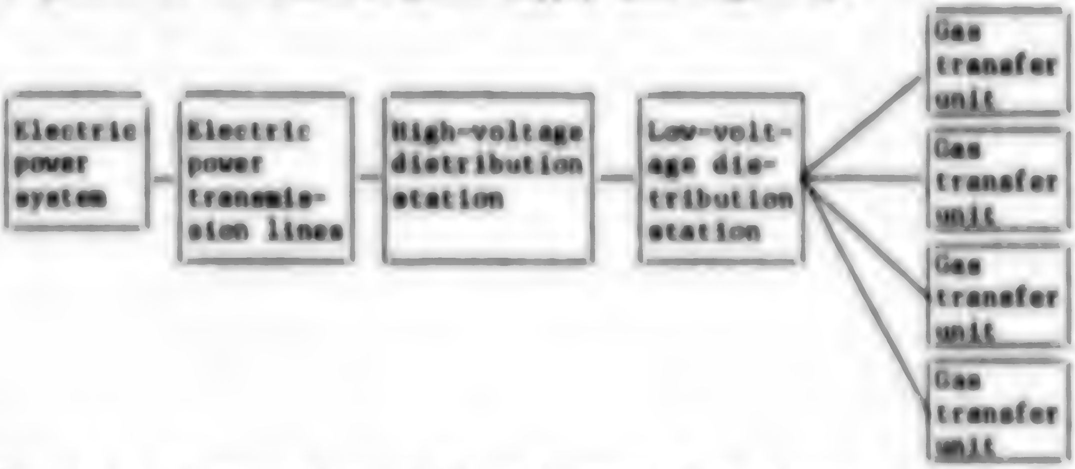
Electric power system
Electric power transmission lines
High-voltage distribution station
Low-voltage distribution station
Gas transfer unit
Gas transfer unit
Gas transfer unit
Gas transfer unit

Figure 1. Structural reliability diagram of an electrically driven pressure station.

In order to discover the effect of individual elements on the operation of the electric power supply systems (SES) materials were gathered on a number of gas mains and at the compressor stations by the operating logs and the documents on emergency shutdowns of the gas transfer units.

In this article a study is made of the data only with respect to one gas main (for the 1974-1977 period) where the statistics turned out to be the most representative and reliable. The total number of EP PGA operated here is 28.

On the basis of the information obtained on 285 forced shutdowns it was established that 125 of them are the result of failures in the electric power supply system, of which 92 are connected with the disappearance or collapse of the voltage on the part of the feed system (by the feed system in the given case we mean the entire electric network to the low-voltage buses).

For the investigated time period, for various reasons 18 disconnects of the overhead electric power transmission lines have occurred; 91 shutdowns were recorded, that is, there were 5 unit-shutdowns for one disconnect. In 15

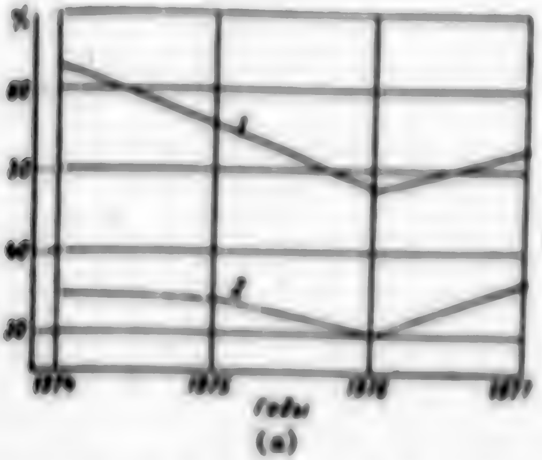

Figure 2. Variation of the number of forced shutdowns as a result of interruption of the electric power supply. 1 -- electrically driven compressor stations; 2 -- gas turbine compressor stations.

Key: a. years

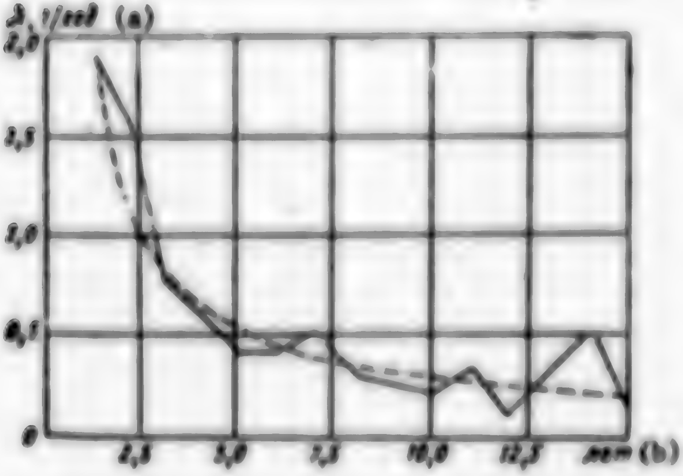

Figure 3. Statistical and theoretical relations for the parameter of the flow of failures of the gas transfer units with STM-4000-2 drive as a function of the operating time.

Key: a. 1/year b. years

cases out of 18 the disconnects occurred with stoppage of the supply of electric power over one of the two lines feeding the compressor stations which, in all cases, led to shutdown of half of the gas transfer units operating at the time of the disconnect.

At the same time the distribution of the unit-shutdowns with respect to cause of interruption of electric power supply looks like the following: overhead electric transmission lines 66.7%, high-voltage distribution stations 9.1%, low-voltage distribution stations 20.2%, violation of the PTE [technical operation rules] 4.0%.

Analogous results were also obtained with respect to other gas mains.

Consequently, the primary source of forced shutdowns and the weak place in the electric power supply systems can be considered to be the overhead electric power transmission lines. The analysis of the causes of disconnection of the overhead electric power transmission lines demonstrated that the basic part of the failures are determined by the weather-climatic factors and are connected with damage to them by outside organizations. This, in turn, makes it necessary to focus special attention on the necessity for considering the climatic and natural conditions when designing the electric power supply systems.

The consideration of the materials of the ORGTEKhENERGO to discover the effect of the weather factors on the damage to the electrical equipment operating in various climatic zones led to the conclusion that the failure flow parameter for the electrical equipment operating in cold climatic zones is very high -- with respect to individual types of equipment it exceeds the national average by 1.5-2 times.

It is known that the operating reliability of the gas transfer units cannot be estimated by any one index. The most complete reliability characteristic of the elements is given by the distribution laws of its failures and the recovery time. When processing the statistical data on the operating reliability of the equipment it is necessary to analyze the following: the distribution functions of the failure times, the number of failures and the recovery times and also the failure flow parameters; the average recovery time; the average frequency and duration of planned disconnects; accuracy and reliability of the statistical estimates; the dependence of the basic indexes on the operating time and the degree of assimilation in production.

Whereas the first six characteristics for the gas transfer units have some numerical characteristics and are partially discussed in the literature, the last characteristic must be discussed separately.

The failure flow parameter as a function of operating time has the shape of a monotonically decreasing curve which is approximated well by the Weibull distribution curve. Figure 3 shows this relation for the gas transfer unit for the STM-4000-2 drive; analogous relations were also obtained for the gas transfer unit with other types of drives. The gas transfer unit with the AZ-4500-1500 drive for which the independence of the failure flow parameter with regard to the operating time is characteristic, constitutes an exception. This is explained by the fact that the available data made it possible to analyze it only in the time interval excluding the possibility of considering the break-in period (8-18 years).

The nature of the relations obtained indicates that the stationary operating conditions are reached after 2-3 years (sometimes after 4 to 5 years) following the date of putting the compressor into operation. The failure intensity during the initial period exceeds its steady-state value by 3 to 4 times. Frequently the explanation for this consists in the fact that during the initial operating period the compressor stations operate by the electric power supply start up systems.

Consequently, one of the methods of improving the operating reliability of the compressor stations is intensification of the construction of electric networks.

We shall touch on the problem of the effect of the startup frequency on the reliability of the electrically driven gas transfer units. Up to now this relation has been determined only for the gas turbine. The failure intensity of the gas transfer units with electric drive can be described by a linear equation of the type $\lambda = a + b\omega_{п}$. The values of the coefficients a and b are presented in the table.

The analysis of the equations obtained indicates that there is a direct relation between the failure intensity and the startup frequency of the electrically driven gas transfer units. Here it must be noted that the STD drive is the most sensitive to startups, and the AZ drive the least sensitive.

Thus, in order to increase the operating reliability of the electrically driven gas transfer units, they must be used when the gas line is operating in the steady-state mode, that is, under conditions of small periodic fluctuations in output capacity. At the same time in case of a change in output capacity of the gas main, it is expedient to use the synchronous motors as the primary motors and asynchronous motors as the peak motors to drive the gas transfer units. It is of interest to investigate the joint use of synchronous and asynchronous electric motors on the electrically driven compressor stations, the more so in that the regulation of the output capacity of the gas transfer unit by varying the rpm of the asynchronous electric motor is connected with fewer technical difficulties and lower material expenditures, whereas the synchronous motor is expediently used as a source of reactive power which is needed to decrease the energy losses in the feed overhead electric power transmission lines and the electric power supply system as a whole.

When performing the practical work of evaluating the cost benefits of one version of the electric power supply system or another, the necessity arises for insuring not only the required reliability but also the maximum economy for minimum expenditures to achieve the desired results.

The optimal degree of reliability considering the losses from interruptions of the electric power supply is determined by comparing the annual reduced expenditures by the known formula

$$Z = p_{н}K + I + Y = \min,$$

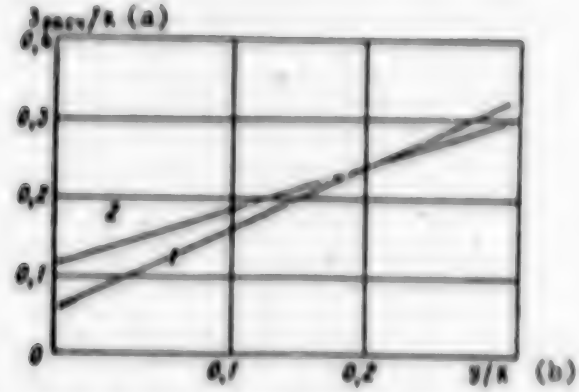

Figure 4. Relative reduced expenditures as a function of the relative loss from interruptions of the electric power supply. 1 -- two-wire electric power transmission feed line; 2 -- two single-wire electric power transmission feed lines.

Key: a. $Z_{calc}/K$ b. Y/K

where $p_H$ is the normative efficiency of the captial investments; K is the capital expenditures on the electric power supply system; I are the operating expenses; Y are the losses from underoutput of electric power.

When comparing the versions, the defining role is played by the capital expenditures and losses which is easily proved in an example.

A study is made of the electric power supply system in two versions: the compressor stations are fed over two single-wire overhead electric power transmission lines and one two-wire line. The version with the two-wire overhead line is taken as the basic version. The increase in capital expenditures on building two single-wire overhead lines, the decrease in operating costs in the version with the two-wire overhead line and the reliability characteristics of lines of both types are taken into account. As a result of the calculations, the following expressions were obtained for the reduced expenditures: for the two-wire overhead line Z= 0.173K + 1.46Y; for the single-wire overhead lines Z = 0.283K + Y.

| Electric drive of the gas transfer unit | a | b |
|---|---|---|
| AZ-4500-1500 | 0.0807 | 0.0660 |
| STM-4000-2 | 0.2370 | 0.1600 |
| STD-4000-2 | 0.2700 | 0.2600 |

The graphical interpretation of the results of the calculation is shown in Figure 4, where it is obvious that the versions are equally economical for an annual loss of 20 to 25% of the cost of the equipment of the two-wire overhead line. With a smaller value of losses from underproduction of electric power from the economic point of view the version with the two-wire overhead electric power transmission line is more acceptable. However, the problem of determining the losses for the gas transport enterprises still remains open.

From what has been stated it is clear that in order to insure the required operating reliability of the compressor stations broad introduction of self-starting of the electric motors that drive the gas transfer units and intensification of the electric network construction in the operating phase are necessary.

In the design phase in order to insure operating reliability of the compressor stations, careful analysis of the natural climatic and geographic factors at the locations of the post compressor stations is required.

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# DISPERSED HYDROCARBONS -- PROSPECTIVE POWER SUPPLY

Moscow GAZOVAYA PROMYSHLENNOST' in Russian No 12, Dec 79 pp 14-17

[Article by V. I. Petrenko, O. F. Sement'yeva, G. V. Rassokhin, I. A. Leont'yev, V. F. Kanashuk, Yu. P. Korotayev, L. A. Il'chenko]

[Text] The investigated mechanism of displacement of disperse hydrocarbons can be used, in the opinion of the authors, to increase the gas, condensate and petroleum extraction.

Under the conditions of the increasing world power shortage more and more attention is being given to the studies connected with the more efficient and complete use of the existing and finding new sources of power.

Up to now basic attention has been given to the hydrocarbon reserves associated with the industrial accumulations of oil and gas.

In the opinion of the authors, at the present time sufficient factual material has been accumulated to approach the estimation of the total extractable reserves of hydrocarbon raw material from theoretically new points of view. We are talking about disperse liquid and gaseous hydrocarbons, by which we mean all of the syngenetic and epigenetic liquid and gaseous hydrocarbons capable of migration which are located within the sedimentary series of the earth's crust and are concentrated in the lithological differences in the collector and noncollector rocks to the argillites and clays. We have provisionally classified as disperse liquid hydrocarbons the residual petroleum within the gas condensate deposits formed as a result of destruction of the petroleum deposits.

At the present time only the oil and gas deposits, the bituminous shales, oil-bearing sands are being worked inasmcuh as, in the opinion of the majority of researchers, the disperse hydrocarbons are not of real industrial value. At the same time the total reserves of the disperse liquid hydrocarbons exceed the reserves of the hydrocarbons associated with deposits. The gas reserves sorbed by the rock and dissolved in groundwater are enormous.

Approximate calculations show that the disperse liquid hydrocarbon reserves even within the structures of the gas and gas condensate deposits are commensurate with the crude hydrocarbon reserves in them calculated by the generally accepted procedure. This can be illustrated in the example of the Kushchevskoye gas condensate deposit.

The amount of disperse organic material, chloroform bitumoid and disperse liquid hydrocarbons in the rock of all lithological differences within the structure of this deposit from the roof to the gas-water contact was estimated.

The estimate was made as follows. The results of the chemical-bituminological studies of the rock of the section revealed in the Western Caucasus foothills which are presented in reference [1] were used. Within the boundaries of the investigated region for the entire section as a whole the rock contains in disperse form 1.35% $C_{org}$ and 0.0942% chloroform bitumoid consisting of approximately 45% liquid hydrocarbons. The indicated values were taken as the initial values for estimating the amount of disperse liquid hydrocarbons.

The total volume of all rock within the boundaries of the Kushchevskaya structure is $3.3 \cdot 10^9$ $m^3$; of them $1.1 \cdot 10^9$ $m^3$ makeup the gas-saturated collectors and $2.2 \cdot 10^9$ $m^3$ go to the noncollectors. For an average density of 2.4 $g/cm^3$ the total mass of the rock will be $7.6 \cdot 10^9$ tons, including $2.6 \cdot 10^9$ tons of collectors and $5 \cdot 10^9$ tons of noncollectors. Consequently, the following ratio of the crude hydrocarbon reserves and the reserves of disperse liquid hydrocarbons is obtained: initial gas reserves $31.4 \cdot 10^9$ $m^3$, initial condensate reserves $2 \cdot 10^6$ tons, disperse liquid hydrocarbon reserves $3.2 \cdot 10^6$ tons. The intial condensate content in the stratal gas condensate mix was 66 $g/m^3$, and the amount of disperse liquid hydrocarbons for the initial gas reserves, 100 $g/m^3$.

Thus, within the boundaries of the Kushchevskaya structure per 1 $m^3$ of initial gas reserves there are 4 kg of organic material, 0.23 kg of chloroform bitumoid and 0.1 kg of disperse liquid hydrocarbons.

Considering that for 1 $m^3$ of gas there is 0.1 kg of disperse liquid hydrocarbons it is possible to estimate the reserves of the latter within the boundaries of the deposits with potential gas reserves in the USSR and the world. In spite of the fact that the values obtained are significant, they can be less than the actual values inasmuch as the disperse liquid hydrocarbons within the deposits are contained in increased amounts by comparison with their content in the rock of the earth's crust [2].

The high content of disperse liquid hydrocarbons can be caused either by collapse of the oil pools or continuing displacement of the liquid hydrocarbons from the source oil clays to the already formed gas and gas condensate pools with submersion of the structures or by the diffusion processes. It is also necessary to consider that the total reserves of the disperse hydrocarbons include the reserves associated with the petroleum structures of the sorbed gaseous hydrocarbons and also the disperse liquid hydrocarbons located outside the boundaries of the gas and gas condensate deposits, the volumes of which have not been estimated by us.

The luminescent studies of cores and studies of microsections of the rock of all lithological differences of the lower Cretaceous and Jurassic making up the sections of the productive series of nine gas condensate deposits of the Krasnodar Kray (Maykopskoye, Leningrad, Starominskoye, Kanevskoye, Chelbasskoye, Krylovskoye, Nekrasovskoye, Yuzhno-Sovetskoye, Ust'-Labinskoye) performed by the authors in recent years made it possible to discover the following.

The bitumen-bearing nature of the highly permeable collectors which are gas-bearing, according to the existing procedure of isolation of them when calculating the gas reserves, as a rule, is insignificant. Juxtaposed with them are the unconditioned collectors and also the rock differences (including clay) overlapping, interbanding and underlying the gas pool have higher bitumen-bearing nature. A component part of the bitumens is the disperse liquid hydrocarbons.

Thus, the greater part of the disperse liquid hydrocarbons is concentrated in the unconditioned collectors and the interlayers of the highly permeable rock differences, which is characteristic for the majority of regions within the sedimentary series [2, 3]. This situation has obviously served as the reason for the fact that the disperse liquid hydrocarbons are not classified as industrially extractable types of raw material. It must be mentioned that within the gas condensate deposits formed as a result of reforming of the oil pools, the largest number of disperse liquid hydrocarbons are concentrated in the form of residual petroleum in the collectors [4, 5].

The analysis of broad field geological material with respect to the gas condensate deposits of the Krasnodar and Stavropol' Krays and also other gas extracting regions of the country will permit a theoretically new and important conclusion to be drawn regarding the possibility of partial extraction of the disperse liquid hydrocarbons within the worked gas and gas condensate deposits.

Thus, when investigating individual wells for their condensate content during the initial period of operation or even before the beginning of working of the deposits, an increased yield of stable condensate was noted, the composition of which differed from the stratal composition. The increased yield of stable condensate was recorded for operation of the wells in depressions larger than the ordinary technological depressions. For example, for complex investigation of well No 30 of the Leningrad deposit with an initial potential $C_{5+}$ content in the stratal gas of 55 $cm^3/m^3$, under individual conditions the stable condensate yield reached 59 to 75 $cm^3/m^3$.

A similar law was observed at the Stepnovskoye, Vostochno-Kamyshanskoye and Orenburg fields.

At the Starominskoye deposit a trend was observed with respect to many wells to sustain the stable condensate yield in the extracted gas on one level for a prolonged period of exploitation of them.

The same effect was also noted on the scale of the fields. For example, additional extraction of condensate in the Leningrad field from 1960 to 1974 amounted to 134,000 $m^3$ [6]. This was caused by the fact that as the stratal pressure was reduced, the actual condensate extraction from the gas exceeded its theoretically possible extraction for the corresponding bed and separation parameters (Figure 1,a). The same thing was observed in the final stage of the working of the Berezanskoye deposit (see Figure 1,b). With respect to the Mirnenskoye deposit, a constant increase in the stable condensate yield occurred which significantly led the increase in the stable condensate yield with a high $C_{5+}$ content in the stratal gas as a result of introduction of wells in the horizon IV (see Figure 2).

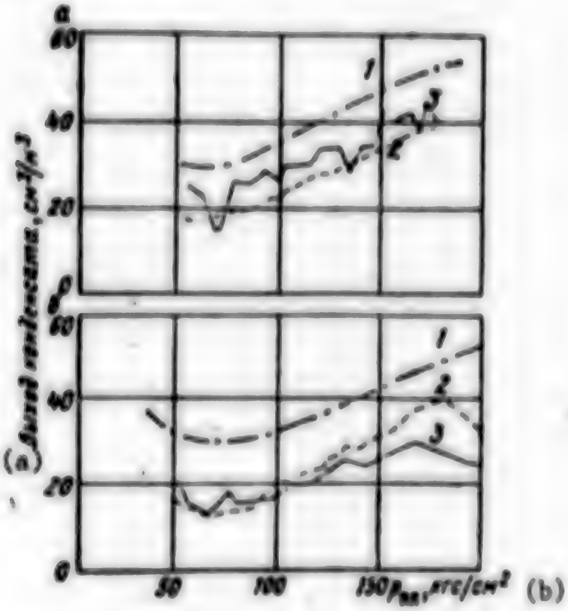

Figure 1. Curves for the variation of the condensate content in the gas of the Leningrad (a) and the Berezanskoye (b) fields. 1 -- current potential condensate content in the extracted gas; 2 -- theoretically possible condensate extraction from the gas for the existing separation parameters; 3 -- actual extraction (yield) of condensate.

Key: a. condensate yield, $cm^3/m^3$
b. $p_{stratal}$, $kg/cm^2$

It is very important that the highest values of the condensate yield are noted with respect to the fields with partial alternation of the productive and nonproductive beds and active selective advance of the encroachment water for which intense flooding of the wells is characteristic.

The above-described examples are explained by partial extraction during the process of working the deposits of disperse liquid hydrocarbons located

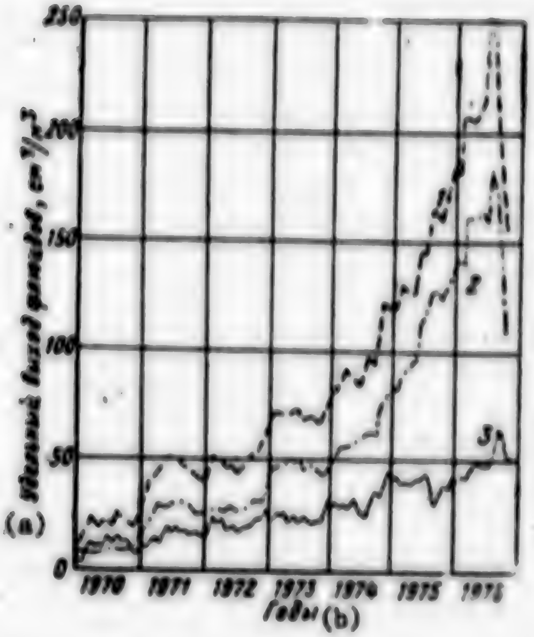

Figure 2. Dyanamics of the liquid, water and condensate yield with respect to the Mirnenskoye deposit. 1 -- liquid (water and condensate); 2 -- water; 3 -- condensate.

Key: a. specific fluid yield, $cm^3/m^3$
b. years

within the structures with pools. On the modern level of studying the given problem the mechanism of extraction of the disperse liquid hydrocarbons from the rock is represented as follows. When working the deposits to depletion, the stratal pressure in the most drained, usually well-permeable beds, drops at leading rates, and a pressure gradient that increases constantly with time arises between the unconditioned collectors, the low-permeable rock differences, including the argillaceous interlayers and the well-drained collectors.

For the defined pressure gradients the disperse liquid hydrocarbons are forced out initially from the unconditioned collectors, and then from the argillaceous interlayers into the highly permeable beds using desorbed and expanding gas and also the water that is squeezed out or in pure form with significant saturation of the pore space of the low-permeable rock differences by it.

The displacement of the disperse liquid hydrocarbons arises from the fact that reduction of the stratal pressure in the pools reaches tens and hundreds of atmospheres which, in turn, leads to the corresponding increase in the vertical effective pressure commensurate with the increase in pressure when submerging the structures with the pools to greater depths during geological time.

It is necessary to note that the pressure gradients occurring in the deposits significantly exceed the limiting filtration gradients even for clays [7]. The calculated liquid hydrocarbons can theoretically be shifted both along and across the bedding of the low-permeable rock differences, but the movement along the bedding has limited significance. Within the deposits along the bedding, large volumes of gas can move to significant distances only from the insufficiently drained or undrained zones with poor collective properties to the well-drained zones with good collectors as a result of the pressure gradient that arises, which was first pointed out by M. A. Bershteyn. However, he investigated the cross flows of industrial gas associated with the collectors and unfailingly considered when calculating the reserves.

The displacement of the disperse liquid hydrocarbons from the unconditioned collectors and impermeable interlayers to the permeable drained beds will have predominance, as a result of the fact that within the limits of even one deposit, as a result of the nonuniformity of the section, the displacement takes place in contact areas of hundreds and thousands of square kilometers during the entire period that the bed is worked. Accordingly, the absolute amount of displaced dispersed liquid hydrocarbons can reach significant values.

The disperse liquid hydrocarbons forced into the collectors can saturate the gas phase of the bed and be transported in the dissolved state; be moved in the liquid state with significant saturation of the pore space of the collector with them; in the case of active specific water pressure they can be displaced by the interstitial stratal water or displaced by any artificially pumped agent.

The indicated mechanism of displacement of the disperse liquid hydrocarbons appears to one degree or another in all gas, gas condensate, gas-oil, oil-gas and oil deposits. The extraction of sorbed gaseous hydrocarbons, the content of which in the noncollectors can reach significant amounts, can play a noticeable role in a number of beds using the described mechanism.

It is unquestioned that the disperse liquid hydrocarbons will play a noticeable role primarily when working such deposits as Mirnenskoye, Orenburgskoye, Vuktyl'skoye.

The problem of the extraction of disperse liquid hydrocarbons must be considered more broadly. The latest studies by the authors have demonstrated that there is a theoretical possibility of extracting disperse liquid hydrocarbons within the water-bearing structures, the bituminous nature of the rock within the limits of which, as a rule, exceeds by several times the bituminous nature of the rock outside the structures [2], and then also for extraction of the disperse liquid hydrocarbons outside the anticlinals. The mechanism of the pressure gradient obviously can be used when working bituminous shales, oil-bearing sands, worked petroleum and gas-condensate deposits, and so on.

Thus, by using the indicated mechanism of displacement of the hydrocarbons we have the prerequisites for the organization in the future of their extraction on industrial scales, which has great national economic significance. It is sufficient to point out that the extraction of 1% of the reserves of the disperse liquid hydrocarbons in the USSR within the limits of the gas and gas condensate deposits with explored gas reserves can yield $26 \cdot 10^6$ tons of hydrocarbons.

The described mechanism of displacing the disperse liquid hydrocarbons also has great theoretical significance, for the migration of the liquid fluids in enormous volumes is observed for the first time within the boundaries of small zones of the earth's crust during a short time period.

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## GAS RESERVE DISTRIBUTION OVER THE MEDVEZH'YE FIELD

Moscow GAZOVAYA PROMYSHLENNOST' in Russian No 12, Dec 79 pp 21-23

[Article by Ye. M. Nanivskiy, V. N. Maslov, T. A. Gavrilovskaya]

[Text] The proposed procedure for estimating the gas reserve of individual sections of a field considering the crossflows permits an objective approach to the distribution of the samples with respect to the bed, which increases the working efficiency and increases the gas extraction coefficient.

The Medvezh'ye gas field was put into experimental-industrial operation in April 1972. With respect to condition on 1 June 1978, it was being pumped by 196 operating wells which were connected to eight complex gas preparation units (UKPG). In this time, 194.8 billion $m^3$ of gas or 12.6 percent of the proven GKZ gas condensate reserves were extracted. The stratal pressure dropped by 8.12% of the initial pressure and was 107.77 $kg/cm^2$.

The staged introduction of the field into being worked at the present time does not permit estimation of the reserves by the method of the stratal pressure drop for the field as a whole. Therefore the reserves were determined for regions operating the UKPG installations. Let us present a more detailed discussion of the calculation procedure inasmuch as it makes it possible to estimate the amount of gas directly involved in the working and insuring the observed rate of reduction of the stratal pressure.

The given method is based on using the material balance equation

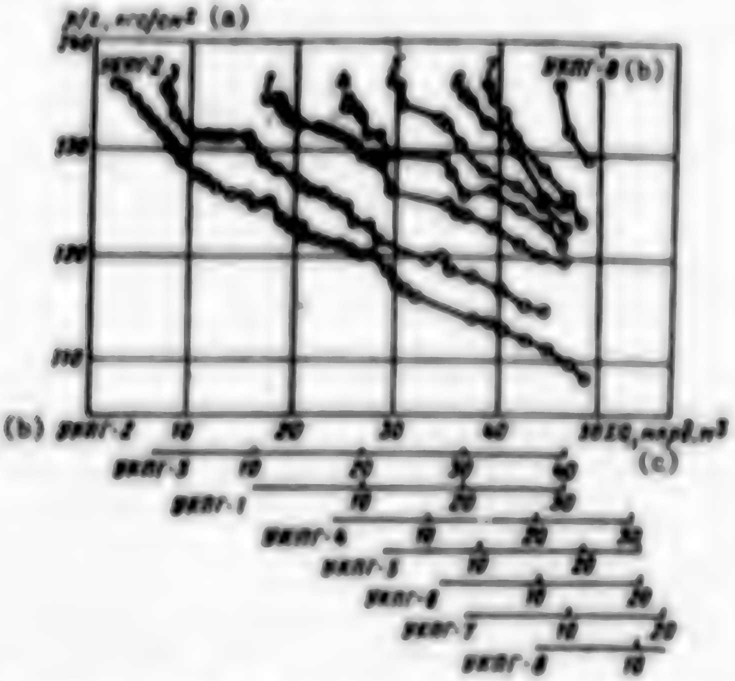
$$\frac{p(t)}{z(p)} = \frac{p_H}{z_H} - \frac{\overset{(1)}{\Sigma Q_{\text{доб}}}(t)\, p_{\text{ат}} T_{\text{пл}}^{(2)}}{\Omega_{\text{н}} T_{\underset{(3)}{\text{ст}}}}, \qquad (1)$$

Key: 1. ext 2. stratal 3. standard

where $p(t)$ and $p_H$ are the current and the initial stratal pressures, $kg/cm^2$; $z(p)$ and $z_H$ are the current and initial compressibility factors; $\Sigma Q_{ext}(t)$ is the amount of extracted gas for the time $t$; $p_{at}$ is the atmospheric pressure

Table 1. Gas reserves found by various methods (in billions of $m^3$)

| Method of determining gas reserves | UKPG | | | | | | | | Total with respect to work section |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| With respect to specific drawn-off volumes | 226 | 266 | 246 | 270 | 184 | 136 | 80 | 85 | 1493 |
| With respect to average pressure of central zone | 250 | 130 | 186 | 258 | 144 | 150 | 82 | 44 | 1244 |
| With respect to average pressure of entire section | 272 | 138 | 200 | 295 | 154 | 161 | 94 | 154 | 1468 |
| For weighting of pressure with respect to total gas extraction volume | 278 | 237 | 245 | 259 | 170 | 144 | 82 | 45 | 1460 |
| Gas reserves found by the volumetric method | 155 | 103 | 141 | 302 | 170 | 115 | 120 | 140 | 1246 |
| Gas reserves found considering crossflows | 229 | 179 | 186 | 338 | 209 | 155 | 80 | 186 | 1562 |



Stratal pressure drop as a function of total gas extraction.

Key: a. p/z, kg/cm$^2$ b. UKPG... c. $\widetilde{\Sigma}Q$, billions of m$^3$

equal to 1.033 kg/cm$^2$; $T_{st}$ and $T_{stratal}$ are the standard and stratal temperature, °C.

Substituting the current values of the reduced stratal pressure and the extraction with respect to the ith well in this equation, we obtain the specific reserves drawn off by the given well[1]. The total reserves of all wells in the section correspond to its total reserves giving rise to the rate of reduction of the stratal pressure. Accordingly, the gas reserves were determined for the regions of the UKPG-1-8 wells. The results of the calculation demonstrated that the maximum total reserves and specific reserves for one well are concentrated in the vicinity of UKPG-4 and amount to 270 and 15.9 billion m$^3$ of gas, respectively. They are minimal in the vicinities of UKPG-7 and UKPG-8. The UKPG-1, 6 and 7 have the greatest nonuniformity of the specific reserves; this is indicated by the comparatively high variation coefficients.

During the process of exploitation of the field, the reserves involved in working the field increased as new wells were drilled. Thus, with respect to the condition on 1 January 1974, 25 wells were involved in the extraction of 285 billion m$^3$ of gas. The specific gas reserves for one well on the average were with respect to UKPG-2, 11.6 billion m$^3$, and with respect to UKPG-3, 10.9 billion m$^3$.

On 1 January 1975, there were 45 wells in operation which drained about 500 billion m$^3$ of gas. Its reserves per well were distributed with respect to the UKPG as follows: UKPG-2 was 11.2 billion m$^3$; UKPG-3 was 10.4 m$^3$; UKPG-1 was 12 billion m$^3$.

At the beginning of 1976, the reserves of drawn-off gas increased to 750 billion m$^3$. The pool of operating wells reached 63. Here the average gas reserves for one well equalized: with respect to UKPG-2, 10.6 billion m$^3$, UKPG-3, 10.8 billion m$^3$, UKPG-1, 10.8 billion m$^3$ and UKPG-4, 13 billion m$^3$.

With respect to the condition on 1 March 1978, the gas reserves found by the specific drainage volumes amount to 1,493 billion m$^3$ for 143 operating wells.

Six years of experience in working the deposit demonstrated that the basic number of operating wells (62-84%) were introduced during the first year of operation of the UKPG. The further introduction of wells had no significant effect on the reserves, which made it possible to evaluate them by the stratal pressure drop method.

The basic results of this calculation for 1 March 1978 are presented in Table 1. The reserves calculated by the volumetric method are given there for comparison.

The analysis of the table data reveals a significant difference in magnitudes

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[1] S. N. Zakirov, B. B. Lapuk, PROYEKTIROVANIYE I RAZRABOTKA GAZOVYKH MESTOROZHDENIY (Planning, Design and Working Gas Fields), Moscow, Nedra, 1974.

Table 2. Gas extraction dynamics for 1 kg/cm$^2$ of stratal pressure drop (in billions of m$^3$/kg/cm$^2$)

| Section of deposit | Working time (end of the year) | | | | | |
|---|---|---|---|---|---|---|
| | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 |
| UKPG-2 | 0.84 | 1.0 | 1.28 | 1.46 | 1.62 | 1.67 |
| UKPG-3 | -- | 0.85 | 1.52 | 1.65 | 1.72 | 1.77 |
| UKPG-1 | -- | -- | 2.0 | 1.9 | 1.8 | 1.95 |
| UKPG-4 | -- | -- | -- | 0.74 | 1.58 | 1.8 |
| UKPG-5 | -- | -- | -- | 0.3 | 1.2 | 1.2 |
| UKPG-6 | -- | -- | -- | -- | 1.0 | 1.01 |
| UKPG-7 | -- | -- | -- | -- | 0.06 | 0.47 |
| UKPG-8 | -- | -- | -- | -- | -- | 0.18 |
| On the whole with respect to the field | 0.84 | 1.85 | 4.8 | 6.05 | 8.98 | 10.05 |

of the reserves determined by the volumetric method and the stratal pressure drop for various versions of its averaging. When averaging the stratal pressure as a whole with respect to the worked section and with respect to the extraction zone, the gas reserves differ insignificantly.

In order to explain what has been discussed, a study was made of the stratal pressure drop as a function of the total gas extraction. The relations are presented in the figure for the investigated UKPG. As is obvious, they differ noticeably from a straight line which is characteristic of the operation of the pool for the gas regime. Thus, for UKPG-2, the rate of reduction of the stratal pressure was retarded after the extraction of 10 billion m$^3$; then again when the gas extraction reached 32 billion m$^3$. The gas reserves calculated by the initial section of the function $p/z = f(\Sigma Q_d)$ are equal to 130 billion m$^3$, and with resepct to the second section, 260 billion m$^3$. The gas extration changed, correspondingly, by 1 kg/cm$^2$ of stratal pressure drop, which is obvious from Table 2.

The variation of the stratal pressure drop rate is connected with expansion of the drainage zone of the gas pool in the vicinity of the UKPG-2 and cross flows of gas from the vicinity of the UKPG-3 wells.

The presence of cross flows of gas between adjacent sections is confirmed by the nature of the behavior of the stratal pressure with respect to the UKPG at the time of introduction of them into operation. For example, with respect to the UKPG-1-3, 4 the stratal pressure was on the average less than the initial pressure by 2.6-3 kg/cm$^2$. With respect to the UKPG-5-8, the difference fluctuates within the limits of 1-2 kg/cm$^2$. The amount of cross-flowing gas for the time $\Delta t$ with a linear filtration law is defined by the formula

$$\underset{(1)}{Q_{\text{перет}}} = \int_{t_1}^{t_2} L_i \Delta p^2 dt, \qquad (2)$$

Key: 1. cross flow

where $L_i \Delta p^2$ is the resistance coefficient of the gas filtration in the bed and the difference of the squares of the stratal pressures of the adjacent UKPG.

For determination of the numerical values of the coefficients $L_i$ and the time of beginning of the cross flows, the actual measurements of the stratal pressure in the operating wells were used.

For each of the investigated UKPG, mathematical relations were selected on the computer for the variation of the reduced stratal pressure as a function of the total extraction and operating time. By extrapolation of the relations obtained to the initial stratal pressure, the amount of cross-flowing gas was determined for the time of introduction of the ith UKPG into operation and the corresponding time of the beginning of cross flows. The coefficients $L_i$ were calculated by the formula

$$L_i = \frac{Q^0_{\text{перет}}\,(1)}{\Delta p^2 (t_2 - t_1)}, \qquad (3)$$

Key: 1. crossflow

where $Q^0_{\text{crossflow}}$ is the amount of cross-flowed gas at the time of introduction of the UKPG into operation; $t_1$ and $t_2$ are the times of beginning of crossflows and the time of introduction of the ith UKPG into operation.

The calculation of the total amount of cross-flowing gas with respect to the UKPG demonstrated its significant role in the overall extraction budget. For example, in the vicinity of the UKPG-2 wells on 1 January 1978, 46.9 billion $m^3$ of gas were extracted. On the same date 14.6 billion $m^3$ flowed into this region from the vicinity of the UKPG-3 wells, which amount to 30% of the extraction. The analogous picture is also observed in the remaining operating sections. What has been discussed determines the necessity for considering the inflowing gas when calculating the reserves by the stratal pressure drop.

Considering what has been stated, the equation (1) assumes the form

$$\frac{p(t)}{z(p)} = \frac{p_н}{z_н} - \frac{\left(\Sigma Q_{\overset{(a)}{\text{доб}}}(t) \pm \Sigma Q_{\overset{(b)}{\text{перет}}}\right) p_{ст} T_{\overset{(c)}{пл}}}{\Omega_н T_{\underset{(d)}{ст}}}, \qquad (4)$$

Key: a. ext b. crossflow c. stratal d. standard where $\Sigma Q_{\text{crossflow}}$ is the total amount of gases flowing in and out.

From equation (4) by simple transformations we obtain the formula for calculating the gas reserves

$$\underset{(a)}{Q_{з}} = \frac{\overset{(b)}{\Sigma Q_{\text{доб}}}(t) \pm \Sigma Q_{\text{перет}}\,(c)}{1 - \frac{p(t)}{p_{н}}\,\frac{z_{н}}{z(p)}} \qquad (5)$$

Key: a. reserves b. extracted c. crossflow

The basic results of the calculations presented in Table 1 indicate that the maximum gas reserves of 338 billion $m^3$ are concentrated in the vicinity of the UKPG-4 wells. The UKPG-2 and UKPG-3 have approximately equal reserves. The total reserves in the southern section of the field are equal to 931 billion $m^3$.

The total drawn-off reserves in the central section amount to 630 billion $m^3$. The largest quantity of gas is found at UKPG-5 and UKPG-8, and the smallest amount, at UKPG-7.

On the whole, the gas reserves with respect to the worked sections are distributed nonuniformly. Thus, the reserves in the southern section exceed by 1.47 times the reserves of the northern section. At the same time the design for working the field provides for the same volumes of annual extraction of 25-27 billion $m^3$ of gas. With respect to the found reserves such extractions amount to 4.3 and 2.7% for the central and southern sections, respectively. As we see, in the sections of the field the degree of drainability is different. To eliminate the existing disproportion in the degree of working, it is necessary to redistribute the gas extraction proportionally to the reserves of the individual sections. For this purpose the gas extraction in the southern section must be increased by 8 billion $m^3$ per year as a result of more intense involvement in the working of the productive zones in the vicinities of the wells of UKPG-1 and UKPG-4. In order to increase the gas extraction in these regions, it is necessary to drill 12 more operating wells each. It is expedient to place these wells in the peripheral zone, which will insure more intense involvement of them in the operation and, consequently, an increase in the coefficients of the industrial gas extraction of the given sections.

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## SIBERIAN DRILLING OPERATIONS: PRESSURE DROP

Moscow BURENIYE in Russian No 2, Feb 80 pp 16-18

[Article by A. P. Pestrov and V. V. Filin, Yuganskneft' Association]

[Text] The profile of the group of oil fields in the Central Ob' region (Tyumenskaya Oblast), which include the Ust'-Balyk and the Yuzhno-Surgut, is represented mainly by rock of soft and medium hardness with die hardness of $p_{sh}$ = 50-60 kgf/cm$^2$ [1, 2]. The rock is conditionally divided into five benches according to physicomechanical properties--drillability--in the geological profile of these fields [2, 3]. The fields are drilled by the turbine method using water-jet bits.

The practice of drilling with jet bits in the Central Ob' region confirms the high efficiency of using these bits with relatively low pressure drops--20-30 kgf/cm$^2$--in them.

It is known that the main operating indicators of jet bits increase significantly with an increase of the pressure drop in them.

Sloping wells with increased pressure drops in the bit were drilled in an experimental-industrial volume at the Ust'-Balyk and Yuzhno-Surgut fields to study the possibility of improving the technical and economic indicators by more complete use of the jet effect. Drilling was carried out with the 3TSSh-195TL turbodrills with 28/18 turbine. U8-6M pumps with productivity of 41 and 44 liters/second were used when using BU-80 BrE drilling rigs to achieve a pressure of 180-220 kgf/cm$^2$ on the riser.

The working pressure of the drilling mode was held within the range of 180-220 kgf/cm$^2$ by equipping the bits with mineral-ceramic nozzles 11-15 mm in diameter, which were selected by drilling intervals according to procedural instructions [4]. The pressure drop on the bits varied from 110-120 kgf/cm$^2$ in the upper intervals and up to 45-50 kgf/cm$^2$ in the lower intervals.

Some hydraulic characteristics of bit operation on rock benches with pressure up to 220 kgf/cm$^2$ at the pump throwout with regard to leakage of

Table 1

| Пачки пород (1) | Условный интервал по буримости, м (2) | Расход бурового раствора, л/с (3) | Перепад давления на долоте, кгс/см² (4) | Скорость истечения из насадок долот, м/с (5) | Гидравлическая мощность, получаемая на долоте, л. с. (6) | Сила удара струи жидкости, л/с·м/с* (7) |
|---|---|---|---|---|---|---|
| I | 400–1160 | 41/44 | 110/95 | 135/125 | 460/488 | 4320/4812 |
| II | 1160–1720 | 41/44 | 100/80 | 121/110 | 453/432 | 4114/4456 |
| III | 1720–2020 | 41/44 | 90/70 | 114/101 | 432/387 | 4104/4192 |
| IV | 2020–2300 | 41/44 | 80/60 | 107/92 | 400/340 | 4012/3910 |
| V | 2300–2750 | 41/44 | 70/50 | 100/84 | 350/287 | 3850/3612 |

*Product of drilling mud flow rate by the flow rate from the bit nozzle.

Key:

1. Rock benches
2. Conditional interval by drillability, m
3. Drilling mud flow rate, liters/second
4. Pressure drop in bit, kgf/cm²
5. Flow rate from bit nozzles, m/s
6. Hydraulic output achieved in bit, hp
7. Impact force of liquid jet, liters/s·m/s

drilling mud through the turbodrill shaft are presented in Table 1. (The data in the numerator refer to the Ust'-Balyk and those in the denominator refer to the Yuzhno-Surgut fields in all the tables).

The drill string was configured from 147-mm pipe with wall thickness of 11 mm and 127-mm TBPV steel pipe with wall thickness of 9 mm and length of 650-750 meters, 178-mm UBT pipe 12 meters long and 190 X 90-mm LBT pipe with sintering device 12 meters long and a turbodrill having stabilizer and calibrator. 5K-146GV, 1K-214SZG, Sh-215.9MZGV, Sh-215.9SGN and Sh-215.9SZGN bits were used as the rock-crushing tools. Water was used to flush the wells at the interval of 400-1,200 meters and drilling mud with density of 1.06-1.18 g/cm³ was used at lower levels. The axial load which was selected from calculation to achieve maximum current mechanical drilling rate varied within the range from 12-14 t-f in the upper intervals to 18-20 t-f in the lower intervals.

Table 2

| Пачки пород (1) | Условный интервал по буримости, м (2) | Средние показатели работы одного долота (3) | | | | Изменение показателей работы долота, % (4) | |
|---|---|---|---|---|---|---|---|
| | | Давление на выкиде насоса 180-220 кгс/см² (5) | | Давление на выкиде насоса 150-160 кгс/см² (6) | | | |
| | | проходка, м (7) | механическая скорость, м/ч (8) | проходка, м (7) | механическая скорость, м/ч (8) | проходки (7) | механической скорости (8) |
| I | 400-1160 | 910/838 | 81,3/71,2 | 812/729 | 72,2/63,0 | 12/14 | 12/13 |
| II | 1160-1720 | 258/304 | 30,9/35,1 | 213/227 | 26,8/29,3 | 21/33 | 15/19 |
| III | 1720-2020 | 128/146 | 18,9/21,9 | 104/121 | 17,1/19,9 | 23/20 | 10/10 |
| IV | 2020-2300 | 94/97 | 15,8/16,4 | 74/75 | 14,0/14,0 | 27/29 | 12/17 |
| V | 2300-2750 | 76/83 | 12,6/15,0 | 64/70 | 11,3/13,0 | 18/18 | 11/15 |

Key:

1. Rock benches
2. Conditional interval by drillability, m
3. Mean operating indicators of one bit
4. Variation of bit operating indicators, percent
5. Pressure of 180-220 kgf/cm$^2$ at pump throwout
6. Pressure of 150-160 kgf/cm$^2$ at pump throwout
7. Drilling, m
8. Mechanical rate, m/hr

The comparative operating indicators of bits by rock benches when drilling with increased and ordinary pressures at the pump throwout are presented in Table 2. The depth of the wells drilled with increased pressure drops was equal to 2,505 and 2,559 and that of wells drilled at ordinary pressures was 2,436 and 2,552 meters, respectively at the Ust'-Balyk and Yuzhno-Surgut fields.

Drilling the wells with increased pressures at the pump throwout also contributed to an increase of regular, technical and commercial rates (Table 3).

As indicated by inspection of bits operated at increased pressure drops on the bit, clogging of the cutters and formation of seals were not observed or were insignificant when drilling in rock benches I and III. This fact

Table 3.

| Показатели (1) | При давлении на выкиде насоса (2) | | Изменение показателей (3), % |
|---|---|---|---|
| | 150—160 кгс/см² (4) | 180—220 кгс/см² (5) | |
| Коммерческая скорость, м/ст.-мес (6) | $\frac{4911}{5220}$ | $\frac{5387}{5651}$ | $\frac{9}{8}$ |
| Рейсовая скорость, м/ч (7) | $\frac{17,7}{18,6}$ | $\frac{20,2}{21,2}$ | $\frac{14}{13}$ |
| Техническая скорость, м/ст.-мес (8) | $\frac{5265}{5395}$ | $\frac{5892}{5747}$ | $\frac{11}{6}$ |

Key:

1. Indicators
2. At pressure on pump throwout
3. Variation of indicators, percent
4. 150-160 kgf/cm$^2$
5. 180-220 kgf/cm$^2$
6. Commercial rate, m/stage-month
7. Ordinary rate, m/hr
8. Technical rate, m/stage-month

indicates improvement of cleaning the bottom and the rock-crushing tool of slurry since seal-formation and clogging of the cutters are observed when the bits are operated in an industrial volume at ordinary pressure drops on them. Similar results were also achieved when drilling at the Samotlor field [5].

Analysis of the experimental data for 25 drilled wells showed that the jet assembly and nozzle of bits did not break down with pressure drops up to 120-125 kgf/cm$^2$ on the bit with 98 percent hollowing of their total number when specific conditions were observed [4].

The time expenditures for repair-preventive maintenance operations were recorded during experimental drilling. This time was taken into account for 17 wells drilled at ordinary pressures and for 12 wells drilled at increased pressures. Data on the repair carried out for types of work are presented in Table 4.

It is obvious from the data given in Table 4 that the number of repair operations and time expenditures on time increase almost twofold when the working pressure on the pump throwout is increased from 150-160 to 200-220 kgf/cm$^2$.

This significant increase of time expenditures for repair operations is explained only by damage to the manifold and other assemblies of the surface part of the circulating system. The remaining types of repair and preventive maintenance operations are practically independent of the pressure increase in the circulating system. Failure of the assemblies and parts of the surface part is explained by the low quality of the materials used and the insufficiently high technical level of equipment installation.

Table 4

| (1) Ремонтируемый узел — вид ремонта | При давлении на выкиде насоса (2) | | | | | |
|---|---|---|---|---|---|---|
| | 150—160 кгс/см² (3) | | 170—190 кгс/см² | | 200—220 кгс/см² | |
| | число ремонтов (4) | затраты времени* (5) | число ремонтов | затраты времени* | число ремонтов | затраты времени* |
| Манифольд (6) — сварка в местах повреждения, смена резиновых уплотнений и т. д. | 6 | 0,53 | 8 | 0,60 | 16 | 2.00 |
| Стояк, буровой рукав, вертлюг — смена прокладок и сальников (7) | 17 | 1,0 | 16 | 1,08 | 16 | 1,33 |
| Пневмозадвижки — смена посадочных гнезд (8) | 26 | 0,51 | 28 | 0,58 | 31 | 0,87 |
| Итого (9) | 49 | 2,04 | 52 | 2,26 | 63 | 4,20 |

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*For one well

Key:

1. Assembly to be repaired--type of repair
2. At pressure on pump throwout
3. kgf/cm$^2$
4. Number of repairs
5. Time expenditures
6. Manifold--welding at damaged points, replacement of rubber seals and so on
7. Riser, drilling holes and swivel--replacement of packing and stuffing boxes
8. Pneumatic slide valves--replacement of seats
9. Total

Thus, an increase of pressure drop in the bit from 20-30 to 50-120 kgf/cm$^2$ contributes to improvement of the technical and economic indicators of well-drilling--sinking to the bit, mechanical, ordinary, technical and commercial rates, which is explained by the more effective cleaning of the bit and bottom of the well of drilled-out rock. The required pressure drop in the bit during the entire run is maintained due to the wear resistance of the nozzles and of the jet assemblies of the bits used themselves.

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## FUELS

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### NEW SUPERHEAVY DRILLING MUD

Moscow BURENIYE in Russian No 2, Feb 80 pp 23-25

[Article by A. I. Brintsev, V. G. Gusev, V. I. Silayev and B. K. Chelombiyev, Pyatigorsk Branch of SevKavNIPIneft' and Stavropol'neftegaz Association]

[Text] The need to use and the results of laboratory-industrial tests of superheavy drilling mud with lead concentrate additives are known [1].

A mineralized clay drilling mud with density of 2.5 g/cm$^3$ or more, produced by making the initial mud heavy only using barite, has been developed at the Pyatigorsk Branch of SevKavNIPIneft' [expansion unknown]. The possibility of producing drilling mud of such high density and its physicochemical properties largely depend on reagent L-7, with which the mud is t treated.

Reagent L-7, used for addition to the plugging mud as a plasticizing agent and seizure retardant, is a dark brown liquid with density of $\rho = 1.28$-$1.36$ g/cm$^3$, pH value of 2.5-3.2, dynamic viscosity $\mu = 6$-$10$ cP and slightly marked surfactant properties. The main components of the reagent are various polysaccharides and polyphenol type compounds. Two-three milliliters of the reagent contains 1 gram of dry matter.

Under laboratory conditions, superheavy drilling muds using reagent L-7 are prepared in the following manner. A 3-8 percent suspension of modified bentonite and a 3-6 percent solution of KMTs-600 are prepared. The suspension and the KMTs-600 solution are then mixed in the ratio of 1:1. Thirty percent NaCl is added to the stabilized suspension. Caustic soda at 40-50 percent concentration is introduced to reagent L-7 until an alkaline reagent with pH = 10.7-11.1 is achieved. The ratio to caustic soda varied from 2:1 to 3:1 as a function of the properties of reagent L-7. The saline bentonite suspension stabilized by KMTs-600 is mixed with different amounts of an alkaline reagent with L-7 and the solution is made heavy by barite to density of 2.5 g/cm$^3$ or more.

Superheavy drilling muds of different compositions containing 1.5, 2.0, 2.5 and 3.0 percent bentonite suspensions, stabilized by 1.5, 2.0, 2.5 and 3.0 percent KMTs-600, were investigated. The content of alkaline reagent with L-7 in the drilling muds varied from 10 to 100 percent with respect to the volume of stabilized mineralized suspension.

The quality and physicochemical properties of the superheavy muds and their thermal and salt stability were judged by the production indicators measured before and after 6-hour heat treatment at 150°C. The results of the investigations are presented in the table.

As can be seen from the table, a 3 percent bentonite concentration in superheavy mud with stabilization of the bentonite suspension by 2.5-3.0 percent KMTs-600 is optimum. The optimum L-7 concentration is 30-35 percent.

It was established during the investigations that the elastoplastic and viscous properties of dispersed solutions on a water base can be effectively regulated by using L-7, which agrees with previously obtained data [2]. The optimum additives of L-7 impart the best indicators of rheological and filtration properties to the superheavy mud and give strength to the structure (composition No 4). The pH of the medium has a significant effect on the thermal stability of the muds. A value of pH = 10.5-11.0 corresponds to the optimum alkalinity. Industrial tests of superheavy drilling mud were carried out at Mozdokskaya well No 3, drilled at the Pyatigorsk URB to a depth of 4,000 meters. The maximum temperature at the bottom of the well was 150°C. The superheavy drilling mud was prepared on the surface using FSM hunting-air pressure mills, MG-2-4 clay mixers, U8-6M drilling mud pumps, receiving tanks with total capacity of 80 $m^3$ and so on. The mud was prepared by the following formula (per 1 $m^3$): 380 liters of water, 1,800 kilograms of barite, 95 liters of L-7, 45 liters of 45-50 percent caustic soda, 100 kilograms of salt, 13.5 kilograms of bentonite and 11.5 kilograms of KMTs-600.

After preparation, 70 $m^3$ of mud with $\rho$ = 2.50-2.52 $g/cm^3$, T = 100-140 s, static shearing stress after 1 and 10 minutes of $SNS_{1/10}$ = 3-9/8-27 $mgf/cm^2$, water yield of B = 2.0-2.5 $cm^3$, filtration crust thickness of K = 0.5-1.0 mm, pH = 10.7-10.4, NaCl content of 300 g/l and stability of 0.00-0.03 $g/cm^3$ was pumped into the well. The ratio of solid matter and water in the solution was T/V = 47.5/52.5 percent (by volume) and with regard to the solid matter content in the reagent L-7 and liquid matter in the caustic soda it was T/V = 49.5/50.5 percent (by volume).

The new formula superheavy drilling mud was used in a test of Mozdokskaya well No 3. The mud indicators over a period of 20 days were as follows: $\rho$ = 2.50-2.52 $g/cm^3$, $T_{500}$ = 100-120 s, $SNS_{1/10}$ = 9-15/27-60 $mgf/cm^2$; B = 6.0-6.5 $cm^3$, K = 1.5-2.0 mm, pH = 10.4-10.5 and stability of 0.00-0.02 $g/cm^3$. Thus, the long duration of the superheavy drilling mud under bottom conditions, drilling out the cement bridge and conducting other operations

| (1) По-ряд-ковый номер | (2) Состав раствора | Показатели технологических свойств (3) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | до термообработки (4) | | | | | | | после термообработки (5) | | | | | | |
| | | ρ, г/см³ (6) | $T_{500}$, с (7) | СНС₁/₁₀, мгс/см² (8) | В, см³ | К, мм | pH | стабильность, г/см³ (9) | ρ, г/см³ | $T_{500}$, с | СНС₁/₁₀, мгс/см² | В, см³ | К, мм | pH | стабильность, г/см³ |
| 1 | (10) Засоленная 40%-ная бентонитовая суспензия с 2,5% КМЦ-600+100% щелочного Л-7+барит | 2,51 | 82 | 54/120 | 2,0 | 0,5 | 10,8 | 0,02 | 2,51 | не течет | Нет свед. | 4,0 | 1,5 | 9,1 | Нет свед. |
| 2 | Засоленная 3%-ная бентонитовая суспензия с (11) 3% КМЦ-600+100% щелочного Л-7+барит | 2,50 | 18 | 6/15 | 1,5 | 0,5 | 10,7 | 0,03 | 2,50 | 15 | 0/3 | 3,5 | 1,5 | 9,8 | 0,40 |
| 3 | Засоленная 3%-ная бентонитовая суспензия с 2,5% КМЦ-600+50% щелочного Л-7+барит (12) | 2,51 | 26 | 12/21 | 2,0 | 0,5 | 10,4 | 0,01 | 2,51 | 20 | 3/5 | 4,0 | 2,0 | 8,6 | 0,15 |
| 4 | Засоленная 3%-ная бентонитовая суспензия с 2,5% КМЦ-600+33% щелочного Л-7+барит (13) | 2,51 | 38 | 9/36 | 2,5 | 1,0 | 10,7 | 0,00 | 2,51 | 26 | 6/30 | 4,5 | 2,0 | 8,7 | 0,00 |
| 5 | Засоленная 3%-ная бентонитовая суспензия с 2,5% КМЦ-600+20% щелочного Л-7+барит (14) | 2,50 | 62 | 30/81 | 3,5 | 1,5 | 10,5 | 0,00 | 2,50 | не течет | 195/270 | 6,0 | 2,5 | — | 0,00 |
| 6 | Засоленная 25%-ная бентонитовая суспензия с 3% КМЦ-600+20% щелочного Л-7+барит (15) | 2,50 | 16 | 3/9 | 2,0 | 1,0 | 10,6 | 0,02 | 2,5 | 15 | 0/3 | 4,0 | 2,0 | 8,7 | 0,22 |

Key:

1. Ordinal number
2. Composition of mud
3. Indicators of technological properties
4. Before heat treatment
5. After heat treatment
6. g/cm³
7. Seconds
8. mgf/cm²

[Key continued on following page]

9. Stability, g/cm³
10. Saline 40 percent bentonite suspension with 2.5 KMTs-600 + 100 percent alkaline L-7 + barite
11. Saline 3 percent bentonite suspension with 3 percent KMTs-600 + 100 percent alkaline L-7 + barite
12. Saline 3 percent bentonite suspension with 2.5 percent KMTs-600 + 50 percent alkaline L-7 + barite
13. Saline 3 percent bentonite suspension with 2.5 percent KMTs-600 + 33 percent alkaline L-7 + barite

[Key continued from preceding page]:

14. Saline 3 percent bentonite suspension with 2.5 percent KMTs-600 + 20 percent alkaline L-7 + barite
15. Saline 25 percent bentonite suspension with 3 percent KMTs-600 + 20 percent alkaline L-7 + barite

essentially had no effect on the indicators of the technological properties of the mud.

The cost of the new superheavy drilling mud is much less than that of mud with lead concentrate. The saving comprises 230-235 rubles per 1 $m^3$ with preparation of the mud alone.

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# DRILLING MUDS ON SAKHALIN ISLAND

Moscow BURENIYE in Russian No 2, Feb 80 pp 28-29

[Article by G. A. Il'in, SakhalinNIPIneft']

[Text] The main characteristics of the geological structure of the oil fields of Sakhalin Island are the presence of a large number of tectonic disturbances and the deformity of rock, the sharp lithological variability of deposits of the same age up the strike within even a single area, the presence of large masses in the profile (more than 2,000 meters) of unstable clay rock, specifically argillites, and the wide range of variation of dead pressures from abnormally low (ANPD), equal to 0.4 $P_{gdr}$ ($P_{gdr}$ is the hydraulic rupture pressure) to abnormally high (AVPD) with abnormality coefficient of 2.1.

It is difficult to drill the wells due to the presence of rock collapses, the sharp deterioration of mud quality (an increase of viscosity) and sudden seizures of the tools with complete loss of circulation, mainly in the intervals where rock of the clay complex is deposited.

The use of calcium chloride drilling mud when drilling the indicated rock at wells 510, 511 and 512-Ekhabi and well 1015-Ts. Okha did not produce positive results. The intensity of the talus and collapses with transition to drilling using calcium chloride marks was increased. For this reason a search was made for new formulas of drilling muds which provide stability of clay rock.

The basis of this search was the method of determining the percentage of collapsed rock as a result of aging it in a drilling mud filtrate at temperature and pressure corresponding to well conditions. It was established as a result of the investigations that the most acceptable muds for clay rock of the fields of Northern Sakhalin are those whose filtrate contains calcium chloride or aluminum sulfate.

Thus, the weight of the collapsed particles from each specimen did not exceed 4.5 percent as a result of aging the specimens for 10 days in a one-percent calcium chloride solution at 80°C and at pressure of 250 kgf/$cm^2$, while the weight of collapsed particles from specimens placed in a one-percent aluminum sulfate solution comprised 3-6 percent of the initial weight of the specimen. At the same time, when these specimens were aged in a one-percent calcium chloride solution, the weight of the collapsed particles comprised 17-20 percent.

Heavy oil-emulsion polymer mud used when drilling wells No 3 and 7-Evay to a depth of 4,380 and 4,511 meters, respectively, provided good indicators. The low values of water yield and the significant increase in the density of this solution ensured successful testing without complications in the intervals of 3,400-4,380 meters in well 3-Evay and 3,414-4,511 meters in well 7-Evay.

The oil content in the drilling mud was maintained at 17-20 percent when drilling the indicated intervals. The mud was stabilized by effective water yield reducers (metas and KMTs-600), which provide a low level of water yield of the drilling mud and stability of the technological parameters during drilling. Nitroglycerine and okzyl were used as viscosity reducer. The positive experience of drilling wells 3 and 7-Evay showed that oil-emulsion mud stabilized by acrylic copolymers and made heavy in time to the required density, provides successful drilling of wells in unstable clay masses.

Practically all wells whose profile includes unstable clay deposits are now drilled by using mud of the given type.

The results of experimental-industrial use of muds based on invert emulsions merit attention. Four wells: No 90-Odoptu, No 1546-Ts. Okha, No 6-N. Val, and No 176-Tungor, were drilled by using them.

The main purpose of the BIER tests at well 90-Odoptu was to determine the effectiveness of using the given systems when drilling seizure-hazardous intervals. The profile of the Odoptu area is complicated by permeable rock, which led to frequent seizures of the drilling and casing strings. Wells in the Odoptu area are largely sloping and the angles of inclination of the shaft reach 30-40°. Seizures usually occur during cooling of the drill string without movement in the well even for a short time (5-10 minutes).

There were three seizures each for each well drilled in 1975 in this area. Drilling of well 90-Odoptu showed that the use of BIER completely eliminates seizures of the drill string. Four accidents with breaking of the drill pipe at the point of a sharp bend of the coumn occurred when drilling the well. Circulation was restored at pressures equal to operating pressures upon correction of the emergencies after the broken tool was joined to the remaining part of the drill string. The drill string was removed from the well without tightening.

If the surface equipment failed during operation, the drill string was in the well without rotation and flushing for 15 hours, while the 146-mm operating string was in the well for three hours. Such prolonged shutdowns do not result in any complications whatever.

The purpose of using BIER when drilling well 5-N. Val was to determine the effectiveness of using the given systems when drilling intervals which have a tendency toward crumbling and collapse. Drill was carried out in the interval of 2,017-3,709 meters. It was established that the use of BIER eliminates collapses of the well walls, complicated by unstable clay rock. Sinking to the bit when drilling the given interval increased 1.5-fold while retaining the mechanical rate of sinking at the same level, while the commercial rate increased 2.5-fold. All the wells drilled prior to this were not brought to the design depths due to crumbling and collapses of the well walls.

The reasons which delay wide use of BIER are their relatively high cost, significant difficulties related to utilization after drilling and also the difficulty of secondary use due to lack of roads and the long distances between wells.

Conversion of ordinary drilling mud to an invert emulsion at well 1546-Ts. Okha and well 176-Tungor made it possible to achieve a sharp reduction of expenditures to utilize the mud replaced (50 percent), a reduction of idle times of the drilling equipment during preparation of the BIER and replacement of one mud by another, which in the final analysis leads to a reduction of the cost of the BIER.

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FUELS

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# CEMENTING TECHNOLOGY IN FIELDS WITH ABNORMALLY HIGH BED PRESSURE

Moscow BURENIYE in Russian No 2, Feb 80 pp 29-31

[Article by A. A. Tsybin, A. A. Gayvoronskiy, B. N. Isayev and G. A. Pakhmurin, VNIIBT and Turkmenneft' Association]

[Text] Gas and oil shows in the space of wells outside the pipe are typical for most oil-bearing areas with abnormally high bed pressure (AVPD) while waiting for the cement mortar (OZTs) to harden immediately after cementing the wells is completed.

One of the main reasons for the development of these shows during OZTs, as is known, is a drop of active hydrostatic pressure of the plugging mud column to the walls of the well during hardening.*

Significant structural changes (mainly during the period preceding the beginning of seizure) occur after completion of pumping the plugging mud into the space around the pipe and after it is left at rest, which accelerates reduction of the hydrostatic pressure by the plugging mud on the walls of the well. This phenomenon is related to the fact that sedimentaton of the cement particles, accompanied by formation of spatial coagulation structure (skeleton) in the water-saturated mud, whose strength gradually increases in time, occurs during the state of rest. The lateral column pressure of the plugging mud on the walls of the well, consisting of the hydrostatic pressure of the excess water and the horizontal pressure component of the formed structure, will decrease as the plugging mud sets up and hardens. It was established by experimental investigations that the pressure of the plugging mud column at intervals where permeable rock is deposited decreases much more rapidly than in intervals where impermeable rock is deposited.

The time $T_v$ during which the hydrostatic pressure of the cement mortar column decreased to the pressure created by a water column similar in height

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[*] A. A. Gayvoronskiy, "Raschet i tekhnologiya krepleniya neftyanykh i gazovykh skvazhin" [Calculation and Technique of Strengthening Oil and Gas Wells], Moscow, Nedra, 1969.

was determined at VNIIBT (All-Union Scientific Research Institute for Drilling Techniques) for plugging muds of more than 20 formulas.

Experiments showed that the value of $T_v$ can be regulated over a wide range by additions of calcium chloride, KMTs and other reagents. Thus, the value of $T_v$ increases 1.5-1.6-fold in cement mortar of the Vol'skiy Plant with v/Ts = 0.5 due to additives of 0.1-0.2 percent KMTs with slight variation of the setting times, while it decreases by a factor of 1.4-1.7, respectively, when 2-5 percent calcium chloride is added.

Another cause of shows in the space around the pipe may be the entry of a large volume of air into the casing string (in the space between the plugging mud and the pressure liquid) and mixing of it with the last portion of plugging mud with which the lower part of the casing string is cemented. The air enters the casing string when the process is stopped after the plugging mud is pumped into it. The greater the difference of densities of the drilling and plugging mud and the deeper the well, the more air enters the casing string. For example, approximately 12 $m^3$ of air may enter a 245-mm casing string lowered to a depth of 1,000 mm with difference of plugging and drilling mud densit es of 0.2 $g/cm^3$.

The following negative properties are typical for plugging mud mixed with air: a decrease of density and as a result a decrease of counterpressure on the walls of the well, formation of cement stone with increased porosity, deterioration of the adhesive quality of the cement stone with the casing string and the walls of the well. The first two negative properties do not require confirmation. The validity of the latter quality is confirmed by analysis of the results of AKTs carried out in cemented wells at fields of the Turkmenneft' Association (Turkmen Petroleum Association). This analysis showed that the coefficient of the adhesive quality of the cement stone with the string and walls of the well fluctuates in the range of 0.30-0.55. If a viscoelastic divider served as a buffer, this coefficient increased to 0.60, but the adhesive quality of the cement stone in the lower part of the casing string remained very low as before and the coefficient of the adhesive quality did not exceed 0.30-0.35. After the plugging mud was pumped into the casing string, its level always decreased due to the difference of mud densities (plugging mud and cement mortar). Removing the locking pins was so difficult due to suction in the divider plug that the delivery line had to be disconnected in some cases and air had to be admitted to the string prematurely.

A special cementation technique, mainly of intermediate strings and conductors, was developed and introduced at the Turkmenneft' Association for the reasons indicated above to improve the quality of cementation and to prevent shows in the space around the pipe of wells during OZTs.

The preventer to prevent a reduction of the mud level in the casing during the time the lock pins on the cementation head are being loosened, the cocks of the main delivery lines are being closed and the cock of the delivery line is being opened was closed immediately after the calculated volume of cementation mud had been pumped in. After completion of preparatory work, the preventer was opened, simultaneously turning on the unit for pressing the separating plug with subsequent start of all the units which deliver the pressing fluid.

In the final stage of pressing down the cementation mud, the last 5-6 $m^3$ of pressing fluid is pumped at reduced flow rate and with stops for 5-10 minutes to bring the total cementation time close to the time of initial setting of the cementation mud. Cementation is completed if further pressing is impossible (a sharp increase of pressure in the cementation units in the absence of delivery according to the readings of the SKTs-2M).

When the "stop" moment is achieved in this manner, sufficiently reliable data on the time of the beginning of setting of the cementation mud and consequently the time of the beginning of a decrease of counterpressure of the cementation mud column to gas, oil and water shows are obtained. A pressure (with regard to the pressure of the hydraulic rupture of the beds), which has increased in stages in time while maintaining conditions so that the total pressure on the beds in the interval of a rise of the cementation mud remained constant, is created in the space around the pipe immediately after completion of cementation to compensate for the decrease of this counterpressure at the wellhead. The pressure at the wellhead in the space around the pipe is released upon completion of the OZTs.

A 245-mm intermediate string lowered to a depth of 3,200 meters was cemented in well 4-Adzhiyab according to the indicated technique. The drilling mud had density of 2.20 g/$cm^3$. The cementation mud with average density of 2.23 g/$cm^3$, prepared from UTsG-2 cement, according to the readings of a KTs-3 consistometer while maintaining counterpressure on the bed and at existing temperature, retained mobility for two hours. SVK was used as a setting retarding agent. The last portion of cement was mixed in sea water without a setting retardant and the mobility of the mud was 1.25 hours.

Cementation was carried out without a separating plug. The mud was initially pressed at productivity of 30-35 liters per second. The productivity of the units was then reduced to 10 liters per second to bring the total cementation time closer to the time of the beginning of setting of the cementation mud. However, the press-down pressure was not increased. All the units were then stopped and aging was carried out for five minutes, after which pressing was resumed. Again no increase in pressure was observed. Similar aging was repeated for 10 minutes. The increase of pressure after restoration of circulation indicated the presence of setting of the cement mortar.

Pumping of the pressing fluid was stopped when pressure of 180 kgf/$cm^2$ was reached.

The preventer was closed and an increase of pressure every five minutes was begun to 30-35 kgf/$cm^2$ until a pressure of 170 kgf/$cm^2$ was achieved, which corresponded approximately to the difference between the expected bed pressure and bottom pressure created by the water column. A cement column 50 meters high was left in the casing string.

More than 10 intermediate columns were cemented at the Turkmenneft' Association according to the given technique. There were no shows in the space of cemented wells around the pipe in all cases of using this technique.

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## URENGOY DEPOSIT YIELDS GAS CONDENSATE

Moscow SOTSIALISTICHESKAYA INDUSTRIYA in Russian 24 Feb 80 p 1

[Article by TASS correspondent, Urengoy: "Difficult Bed"]

[Text] A mighty flow of gas condensate has been obtained for the first time at the Urengoy deposit from a depth of 3,560 meters.

The Urengoy stretches over 100 kilometers from north to south in swampy tundra. This year it should provide practically all the additional output of natural gas in the country. Here over 10 deposits of "blue fuel," located in "levels" have already been discovered. And now there is a new Urengoy level.

The road to it was long and hard. The prospectors of the depths coped successfully with the permafrost, and at a depth of three kilometers they uncovered new deposits with fuel. But it was not possible to penetrate any deeper than 3,500 meters. The guilty factor in the failure turned out to be the anomalously high bed pressure--up to now such a phenomenon had not been encountered in the zone of Western Siberia.

Everything was repeated this time too. But the drillers had taken into account the experience of their colleagues. When samples of dense clays, dark-gray in color--the forerunners of higher pressure here--were raised from a depth of 3,500 meters, the drilling speed was decreased. The bed pressure was measured: it came to over 600 atmospheres. Such a hurricane force still did not subdue the Tyumen' prospectors of the depths.

The Siberians took a long time sorting out the "keys" to this bed. They temporarily closed the well twice. They used especially tough drills, the most unusual fillers. And when the bed was subdued, they continued drilling to the 3,708 meters mark. Special studies showed: the new bed had a high content of gas condensate.

"The discovery of the new complex makes it possible to strengthen the gas condensate base of Urengoy," said the deputy chief of the All-Union Tyumen'gazprom Industrial Association, L. Kosukhin. "Now we are preparing for industrial extraction of this important raw material."

This year the Tyumen' geologists will drill 1,250,000 meters of exploratory wells, over one and a half times more than last year's figure. This means there will be new discoveries.

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## OIL PRODUCTION DISRUPTED AT LENINNEFT' FIELDS

Baku VYSHKA in Russian 27 Mar 80 p 3

[Letter by A. Amirov, foreman, and Abdul Alekper ogly and E. Alisafazade, operators in the shop for extraction of oil and gas, No 6, Leninneft' NGDU, and commentary by V. Gol'tsev: "Who is Responsible for the Disruption in Oil Extraction?"]

[Text] Letter

The collective of our shop No. 6 for extraction of oil and gas, just as other oil fields of the Leninneft' NGDU [Oil and Gas Extracting Administration], is working the oldest oil sites in the country. The beds here are greatly depleted and, in order to extract fuel from them it is necessary to expend a great deal of labor, knowledge and energy. But our collective, overcoming the difficulties, is successfully fulfilling the plans and the pledges made. Last year we extracted about 800 tons of liquid fuel above the assignment.

We have made a good start this year, too. Having started a shock watch in honor of the 110th anniversary since the birth of V.I. Lenin, the 60th anniversary of Soviet Azerbaijan and the formation of the Communist Party of the republic, the oil workers are persistently seeking and putting new reserves into operation, they are carrying out different geological and technical measures which will provide the maximum yield of the oil bed. Our efforts have brought good results. In the past two months more than 40 tons of oil were extracted to the credit of the pledges made, and by the glorious anniversaries we intend to pump into the reservoirs at least another 50 tons of fuel above the plan. However our plans at present are under the threat of being disrupted. Why is this? We will say it frankly: it is due to the regular suspension in the supply of electric power. Here are some specific examples.

On the 10th of March all 235 wells of the field were stopped due to the lack of current. There was no electric power for 25 minutes, and when it was supplied it turned out that the operation of 14 wells with a daily yield of 32 tons of oil had complications.

There was also a disconnection of the electric power on 15 March: there were two stoppages of wells for 10 minutes each. This time there were complications in the operation of 11 wells with an average daily yield of 28 tons of oil.

But we suffered the greatest damage on 17 March, when at various times of the day "Azglavenergo" disconnected our facility three times for a total of 30 minutes.

Interruptions in the electrical supply to field facilities also occurred on 18 March. The total losses of oil in four days came to 100 tons. In addition, many wells reduced their yields, and went out of service for preventive repairs.

The kind of serious complications caused even by a short disconnection of electric power is evident in the example of well No. 2478, located in the section of foreman Mukhtar Kagramanov. This well was operating with an average daily yield of three tons of oil per day. After the stoppage a sand plug 40 meters in size was formed in it. It took 48 hours to clean it, and this means that we lost 6 tons of clean oil. A pump got wedged in well No. 2105, which had stably pumped four tons of oil, and it was necessary to send people here to remove the pump. Altogether during these days all six brigades for underground repair of wells serving our field were engaged in eliminating the consequences of the stoppage in the supply of electric power. And this prevented us from performing the planned geological-technical measures from which the collective had counted on producing a 10-ton daily increase in oil.

Now each of us is applying all of our effort in order to bring the wells to the optimum technological operating regime as rapidly as possible, to insure fulfillment of the plan and the pledges made. But, honestly speaking, we are very anxious about having no repeat of what has occurred.

Commentary

The VYSHKA correspondent showed this letter to the chief of the production-technical division of the Leninneft' Oil and Gas Extracting Administration, N. Manyukhin.

"All that is written there is absolutely correct," he said. "But stoppages of the wells due to cessations in the supply of electric power have also occurred at other fields of the administration. Altogether from 10 through 18 March 11 stoppages of wells were noted due to the fault of Azglavenergo. In addition, on 11 and 18 March due to the lack of electric power the work of 2,956 wells was brought to a halt, that is, almost all the operating fund. The greatest damage here was suffered by the oil field workers of shop No. 6 where all the wells were paralysed with an average daily yield of 260 tons of oil. Altogether the losses in extraction for the administration came to more than 360 tons."

However it is not just a matter of the clear losses of fuel. At the old sites, where there is a great deal of sand in the output of the wells, any unforeseen stoppage, as is correctly noted in the letter of the oil field workers, causes serious complications: large sand plugs are formed, the deep pumps go out of order, the electric motors burn out. It is necessary to expend a great deal of money and labor of people in order to restore the former operating regimes.

We were interested in how matters stand regarding electrical supply in other oil and gas extracting administrations of Azneft'. The chief of the division of main power engineering of the association V. Dzhamalov said that short-term interruptions in the supply of power were also observed in the Siazanneft', Azizbekovneft', Neftechalaneft' and other administrations. In Ordzhonikidzeneft', for instance, in March shut-offs of electric power occurred 13 times. The overall losses of oil came to 1,100 tons. In addition, 45 electric motors broke down, including three motors with a capacity of 100 kilowatts.

The drilling enterprises are bearing serious losses. In the Neftechalinsk UBR [Drilling Administration], as a rule, every day in the morning and evening five-six boreholes stand idle. On 15 March there was a 15-minute stoppage in the supply of electric power to drillholes of the Siazan' Drilling Administration which are located in the mountain region of Zagly-Zeyv. Due to disconnections of electric power in the course of whole days sometimes the drillholes of the Gobustan Drilling Administration in Zardob stand idle, and this happens for several hours during the day in Muradkhanly and at other projects. All this has led to the point where the drillers of Azneft' lost more than 1,000 meters of tunneling in March, and the losses came to over 28,000 rubles.

These are figures which should be given some thought in Azglavenergo. It must be assumed that the people's controllers will also take effective measures here in order to bring order to their own business, to insure uninterrupted supply of electric power to the oil workers, to insure normal operation of the oil fields and drilling enterprises.

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## FUELS

### GAS LINE CONSTRUCTION ENCOUNTERS SOME DELAYS

Moscow PRAVDA in Russian 3 Feb 80 p 3

[Article by Yuriy Kaz'min: "Energy of the Depths"]

[Text] Gas is a priceless gift of nature. Today the operation of industrial enterprises and the normal life of the people are inconceivable without this high-quality energy carrier and very valuable chemical raw material. Last year 407 billion cubic meters of the "blue gold" were supplied to the country's national economy. The increase in extraction came to over 34 billion cubic meters.

The country's gas industry overfulfilled the planned quota for 1979 and the four years of the five-year plan. Toilers in the sector were warmly congratulated on their victory by comrade L.I. Brezhnev.

Uninterrupted operation of all units of the Unified System of Gas Supply for the USSR will depend in the final year of the five-year plan also on the ability of the operators and builders to concentrate their forces on the main underway projects. One of these is the underground transport system from Urengoy to Chelyabinsk. Here it is necessary even in February to put into operation three compressor stations, and crossings across the Irtysh and Salym rivers. And in the second quarter labor-intensive crossings through the Ob', Irtysh and Bol'shoy Yugan should be put into operation, along with the second line of the underground Urengoy-Vyngapur artery.

Today the collectives of the Ministry of Construction of Oil and Gas Industry Enterprises are striving to activate the work also on other underway projects for 1980: the Chelyabinsk-Petrovsk and Petrovsk-Novopskov transport systems. These projects will yield a significant increase in gas deliveries. Where have the delays occurred? First of all at the compressor stations, the river crossings, and the operations for electrochemical protection of the trunk lines from corrosion. In the gas-transport system from the Nizhnevartovsk Gas Refinery to Parabel' to the Kuznetsk Basin there is a delay in laying the branches to the cities of Novosibirsk, Tomsk, and Kemerovo, and the construction of siphons and compressor stations is being delayed.

It must be remembered: rapid bringing of projects that are remote from population centers to the planned limits is conditioned to a significant degree by the creation of normal living amenities for the collectives engaged in servicing the underground lines. But here the worker settlements for the operations personnel are being erected in the last phase.

A no less important task for this year is the creation of the necessary reserve of capacities for reliable supply of gas for the country in the 11th Five-Year Plan. The construction site of the gas industry has been extended broadly to the vast spaces of Siberia and Central Asia, the Volga region, the European Center and the North. The main direction of operations is a many-thread transport system of gas pipelines from Urengoy to Punga to Ukhta to Gryazovets to Torzhok. Namely here will the sector's reserve be created for a successful start in the 11th Five-Year Plan.

The gas workers have resolved to complete the 10th Five-Year Plan on 15 December and to produce 3 billion cubic meters of "blue gold" above the annual plan.

We wish them success!

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## NEW VESSEL REPORTS FOR CASPIAN DRILLING

Moscow PRAVDA in Russian 10 Mar 80 p 1

[Article: "From the Bottom of the Caspian"]

[Text]

A new specialized ship, capable of tunneling at depths of 500-600 meters using a hose-cable, is proceeding to the "28 Aprelya" oil and gas deposit in the Caspian (Azerbaijan SSR) for drilling. The drilling on the new ship will be performed by an advanced brigade of drillers headed by V. Kornevyy. In the photo: the ship, "Spetssudno-1" goes out to sea.

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